TRUCK TRANSPORTATION COSTS OF BULK MILK

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ABSTRACT

Bulk-milk truck transportation costs are estimated over trip lengths from 100 through 1,500 one-way miles. Model truck firms are developed for these cost estimates based on information on operations and costs obtained from nine milk-trucking firms in 1976. Total trip costs for specified trip lengths are analyzed for several alternative situations and projected to 1985 on the basis of mileage, hundredweight, and hundredweight per mile. Total transportation functions are developed from the cost data.

Key Words: Milk transportation costs, Transportation, Trucking costs.

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SUMMARY

Increasing road weight limits for trucks is the most effective way to reduce the cost of hauling bulk milk. If maximum road weight limits were increased from the present 73,280 pounds to 80,000 pounds in key dairy States, hundredweight costs could be reduced an average of 7 percent.

Increasing the speed limit to 65 miles per hour would reduce hundredweight costs an average of 2 percent, but a 10-cent gas tax hike would increase costs 3 percent. Trucking costs for hauling bulk milk are expected to rise 40 to 50 cents per mile by 1985.

Only 18 States and the District of Columbia restricted road weight limits under 80,000 pounds in 1976. But seven of these--Illinois, Indiana, Iowa, Minnesota, Missouri, Pennsylvania, and Wisconsin--were key milk-producing States. Just two top dairy States--California and New York--permitted 80,000-pound loads.

Costs for long-distance truck transportation of bulk milk were developed using synthetic cost analysis. Information from nine hauling firms in the Midwest and Northeast were used to develop model trucking firms of 10 tractors and 13 bulk-tank trailers. Each of the 5,750-gallon tanks was loaded at 47,500 pounds to meet total road weight limits of 73,280 pounds.

The 1976 costs for a model firm were determined and used as a baseline for comparison with other variables. Cost changes were calculated for alternative truck valuation, seasonality, plant unloading, average speed, fuel tax, and tank size.

For example, at a trip length of 500 one-way miles the baseline model produced a cost per hundredweight per mile of 0.234 cent. The cost per hundredweight per mile at this trip length was lowered to 0.223 cent for trucks valued at average costs rather than new costs, 0.219 cent for no seasonality in hauling, 0.223 cent for round-the-clock plant unloading schedules, 0.229 cent for a 10-mile-per-hour increase in the speed limit, and 0.217 cent for an increase in the road weight limit to 80,000 pounds. In contrast, the cost per hundredweight was raised to 0.242 cent for a 10-cent increase in the Federal fuel tax.

Finally, transportation costs were projected to 1985. The projected cost per hundredweight per mile at the 500 one-way miles trip length was 0.297 cent.

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INTRODUCTION

Transportation costs were estimated for over-the-road bulk-milk trucks for round-trip lengths from 200 through 3,000 miles. The costs are for spring 1976. The study follows the general methodology of earlier transportation cost reports by Boles, Kerchner, and Moede (2, 4, 5). 1/

Milk transportation is a large industry with many types of hauling which were not included in this study. Neither the pickup cost of milk at the farm nor the direct movement of milk from farm to processing plant was included. Receiving station or reload station facilities and costs were not included either.

The costs of milk transportation have increased rapidly in recent years. To determine these costs, nine selected milk-hauling firms in Wisconsin, Minnesota, Iowa, Indiana, New York, and Pennsylvania were interviewed. In addition, equipment and building dealers, insurance companies, and various governmental agencies were also used to aid in the estimation of some of these costs.

The bulk-milk trucking firms interviewed ranged in size from 12 tractors with 4 bulk-tank trailers to 55 tractors with 80 bulk-tank trailers. The bulk tanks ranged in size from 5,600 gallons to 6,200 gallons with over 80 percent of the tanks being in the 5,700- to 5,750-gallon size range. In addition, all of the firms had at least a few vans which were used to transport manufactured dairy products. These vans did not appear to affect significantly the utilization of bulk-milk equipment.

1/ Underscored numbers in parentheses refer to references listed at the end of this report.

All firms interviewed had the capability of both short- and long-trip distances. Although one firm did not make any round trips over 400 miles long, the round-trip lengths for the rest of the firms averaged about 20 percent of the trips up to 200 miles, 50 percent from 200 to 499 miles, 25 percent from 500 to 999 miles, and 5 percent of 1,000 miles and over.

The operating conditions of the above sources were used to construct model trucking firms, from which the operating costs for this study were derived. These model trucking firms were assumed to be terminal-based operations located on 5 acres with 4,500 square feet of storage space capable of all necessary repair work. The operations included 10 truck tractors and 13 tank trailers. The trailers each had a capacity of 5,750 gallons.

The above number of tractors is large enough to achieve most economies of size and to be representative of a longrun milk-hauling operation. This excluded owner operations with one or two trucks and their representative cost situations. Most economies of size in the trucking of livestock products are apparently achieved with a relatively low number of trucks (3).

The minimum size of 10 tractors allowed partial use of internal fuel supplies, insurance discounts, fleet discounts on revenue equipment, and a competitive rate of interest due to a long-established line of credit. It also allowed partial separation of the management, dispatching, bookkeeping, and repair tasks.

The costs are presented as single average estimates for a few specified conditions and assumptions. The size and method of operation of the milk haulers assumed for this study were felt to be representative of a typical industry firm as a result of information derived from visits with haulers and industry trade representatives. There was no effort to cover the wide range of possible conditions and their resultant possible differences in costs, either by firm or by region, under which milk haulers often operate.

These costs are initially presented as total cost per mile and are also broken down into fixed, semifixed, and variable costs per mile for selected trip lengths. In addition, transportation costs are also presented as cost per hundredweight and cost per hundredweight per mile. Finally, several alternative cost situations are analyzed for comparison where selected hauling conditions were changed.

TRUCK UTILIZATION

The activities required per trip were determined on an hourly basis for round-trip lengths from 200 through 3,000 miles (table 1). It is assumed that each trip length is served on a specialized basis by one or more firms.

Short hauls of less than 200 miles round trip are sometimes made by the type of equipment used in this study. However, short hauls are often made by smaller trucks, either direct from the farm or from receiving stations to nearby manufacturing plants. Because of the mix of equipment types used for short hauls, these trip lengths were not included in the analysis.

Table 1--Estimated average time of activities for selected trip lengths for a bulk-milk truck

Round-trip mileage	Check-out 1/	Loading time 2/	Unloading time 2/	Washing and cleaning tanks 3/	Waiting time 4/	Driving time 5/	Idle time 6/	Total activity
				Hours				
200	0.25	0.75	0.50	0.50	2.00	4.44	8.00	16.44
300	.25	.75	.50	.50	2.00	6.67	8.00	18.66
400	.25	.75	.50	.50	2.00	8.89	8.00	20.88
500	.25	.75	.50	.50	2.00	11.11	8.00	23.11
1,000	.25	.75	.50	.50	2.00	22.22	8.00	34.22
1,500	.25	.75	.50	.50	2.00	33.33	8.00	45.33
2,000	.25	.75	.50	.50	2.00	44.44	8.00	56.44
2,500	.25	.75	.50	.50	2.00	55.56	8.00	67.56
3,000	.25	.75	.50	.50	2.00	66.67	8.00	78.67

1/ Time needed to inspect truck prior to loading and travel.
2/ Loading and unloading assumed to be done at reload station and pumps at processor plant.
3/ Washing and cleaning assumed to be done by clean-in-plant equipment.
4/ Waiting time exclusive of checkout, loading, unloading, and washing.
5/ Based on average speed of 45 miles per hour.
6/ Eight hours per trip are added for unloading at processor plant.

A number of constant and variable times are involved in each trip. These times were derived from interviews with haulers. Certain operations such as driver checkout, loading, unloading, washing tanks, and waiting time were assumed to require a fixed number of hours per trip regardless of trip length. Driving times vary with trip distance and speed.

It was assumed that 15 minutes would be needed before each trip to check out the equipment and prepare it for use. Loading and unloading times vary with the type of equipment used. For example, a pump with a capacity of 185 gallons per minute was assumed for unloading. The times were assumed to be 45 minutes for loading and 30 minutes for unloading. Washing and cleaning tanks required 30 minutes on the average where automatic washers were generally used and more lengthy hand cleaning was periodically used. Waiting time is defined to be in addition to the above times when a truck is waiting to be loaded, unloaded, and washed. It was assumed to be 2 hours total.

U.S. Department of Transportation (DOT) regulations require that a driver must rest for an 8-hour period after 10 hours of driving time. If two drivers are used and a sleeping compartment is provided on the truck, continuous operation of the truck is permitted. This study assumed two drivers would be used for trips requiring over 10 hours in driving time, so layover time is not included in trip times.

The driving time varies with distance and was based on an average truck speed of 45 miles per hour. The actual speed in the West may be higher while in the East it is likely to be lower. This average speed included time for meals and any vehicle inspection required.

Idle time allowed for processor fluid bottling plant restrictions on the amount of time allowed each day for unloading. This varies considerably, with a few plants scheduling 24 hours for unloading while others limit it to 8 hours in the morning and early afternoon to facilitate their bottling schedule. Manufactured product plants are generally less constrained for receiving times. The plant receiving constraint during the week, along with some plant closings on the weekend, was the basis for adding 8 hours of idle time to each trip.

The estimation of total truck utilization is especially important since costs are very sensitive to annual mileage covered. To arrive at the productivity of the equipment, the total number of truck hours available per year was first estimated. This was based on common business practices of the trucking firms interviewed and on the seasonal nature of the over-the-road milk-hauling industry.

A truck available for duty 24 hours a day, 365 days a year, would be available for a total of 8,760 hours. However, this study assumed 157 hours each year as necessary for major repairs and 1 full day every 4 weeks, or a total of another 312 hours, for minor repairs and servicing. This resulted in a truck being available for only 8,291 hours yearly.

In addition, truck utilization is affected by the highly seasonal demand for long-distance milk hauling. Although the definition of capacity to meet fluctuating demand, such as in milk transportation, is somewhat arbitrary,

this study assumed an industry capacity fully adequate for the high-volume months without price-elevating shortages (1). This resulted in some excess capacity during the low-volume months. The high-volume capacity assumption seems to follow current business practices in the industry, which would be expected due to the importance of the product and the unwillingness of consumers to accept shortages of transportation service during peak volume months. Milk transportation is normally counterseasonal to the production of milk, with the highest transportation volume often around October and the lowest volume often in May.

This assumes that no other products were hauled during the low-volume months. The physical nature of milk tankers, the sanitary requirements of the fluid milk industry, and the fact that fluid milk hauling is nonregulated while most other commodities must be transported by regulated carriers all preclude hauling most other products. Some commodities which technically could be transported in milk tankers include liquid sugar, molasses, liquid eggs, and orange juice concentrate. However, interviews with milk haulers indicated that most tend to be specialized in fluid milk or milk products partially due to the above restrictions and also to the traditional development of the business. The alternative assumption of partial utilization of the equipment to transport additional commodities would obviously result in a lower fixed cost allocated to fluid milk hauling than was assumed in this study.

To adjust for seasonality a factor of 1.48, which is equivalent to 68 percent of total hauling capacity, was applied to the total annual hours available (4). 2/ The resultant adjusted number of annual hours assumed for this study was 5,602. This total was used to determine hourly fixed costs.

In addition, the adjusted total annual hours the trucks were available, divided by the time required for specific trips, determined the feasible number of trips per year and the total mileage per year for each trip length (table 2).

COST COMPONENTS

The costs of transportation in this study will be presented from an economic feasibility viewpoint rather than from a tax or business accounting viewpoint. The tax accounting objective is to determine the minimum amount of taxable income and the business accounting objective is to inform management as to income earned. In an economic feasibility study, opportunity costs are often inferred from real costs as in the example of current market interest rates used to infer the costs to the firm of working capital.

2/ The conversion factor of 1.48 was developed by dividing the yearly average volume of milk shipments into the high-month volume from data available at the time of the Kerchner study. No improvements on data sources could be found to update the 1.48 factor and it is still considered a good estimate by this author.

Table 2--Estimated feasible number of trips and yearly mileages for a bulk-milk truck at selected trip lengths

Round-trip mileage	Nonseasonal		Seasonal	
	Trips	Annual mileage	Trips	Annual mileage
200	504	100,800	341	68,200
300	444	133,200	300	90,000
400	397	158,800	268	107,200
500	259	129,500	242	121,000
1,000	242	242,000	164	164,000
1,500	183	274,500	124	186,000
2,000	147	294,000	99	198,000
2,500	123	307,500	83	207,500
3,000	105	315,000	71	213,000

The assessment of economic feasibility involves generalization about many factors, some of which are difficult to qualify. Critical physical factors in assessing the feasibility of milk transportation include firm size, firm location, and type of buildings and equipment. Other factors include the financial condition of the firm and the firm's objective.

The study assumed a satisfactory return on the resources in the milk trucking firm. No funds were allocated to future expansion since these were considered revenues outside of the market rates of return on resources.

The costs were divided into fixed, variable, and semifixed costs. Fixed costs do not vary with the degree of utilization of the trucks. These would be incurred even if no milk was transported. In contrast, the variable costs contain those expense items which are directly related to the number of miles driven. A third cost category, semifixed costs, contains some elements of both fixed and variable costs, as in truck depreciation where it was assumed that obsolescence would occur over time even if miles traveled did not wear out the equipment. At higher annual mileages, wear would cause replacement of equipment before obsolescence occurred. Decisions made on the allocation of a specific cost item such as insurance into fixed, variable, or semifixed, took into account the common business practices of the milk transporters, while occasionally making adjustments due to the economic feasibility viewpoint of this study.

Also, in specifying costs, this study defined revenue equipment as the tractor-trailer unit. Nonrevenue items were defined as all other equipment, buildings, and land.

Fixed Cost

Fixed cost for bulk-milk trucking includes depreciation on the nonrevenue equipment, return to assets, management and office salaries, administrative costs, taxes, and insurance. Total annual fixed cost per truck was $12,866 (table 3).

The first item in table 3, depreciation, allows for the recovery of the cost of an asset over time by showing it as an annual cost of operations. In this study, the depreciation of only the nonrevenue equipment, $364, was assumed as a fixed cost (table 4).

The terminal-based trucking firm was assumed to have an office and shop building, office and shop equipment, and a pickup truck. The shop was assumed to be 60 feet by 75 feet, of prefabricated steel, and with overhead doors 12 feet by 15 feet. The office area was attached to the shop and was 20 feet by 15 feet. The total value of garage and office was set at $38,400. The shop equipment, valued at $12,000, allowed engine overhauls to be completed at the terminal. The office equipment was valued at $2,500. In addition, the terminal was located on 5 commercially developed acres valued at $1,500 an acre.

Table 3--Annual fixed costs per bulk-milk truck, spring 1976

Item	Average cost per truck
	Dollars
Depreciation	364
Return to assets 1/	3,563
Management and office salaries	2,975
Administrative costs	890
State license and miscellaneous taxes	1,250
Federal highway use tax 2/	210
Insurance	3,613
Total	12,866

1/ Includes depreciation on nonrevenue equipment only.
2/ Department of the Treasury, IRS Publication 349, Vehicle Class M, April 1975.

Table 4--Nonrevenue equipment and building depreciation, per bulk-milk truck, spring 1976

Item	Total investment cost	Years of depreciation	Salvage value	Annual depreciation per truck
	Dollars	Years	Percent	Dollars
Shop and office	38,400	25	--	154
Office equipment	2,500	10	10	22
Shop equipment	12,000	10	10	108
Pickup truck	5,000	5	20	80
Total	57,900	--	--	364

For purposes of this study, the return to assets was a fixed cost. It was treated as an opportunity cost and was intended to include any interest payments plus returns to the business as an additional allowance for bearing risks. It was based on a 10-percent return on the midlife value of the assets; the resulting total return to assets per truck for this study was $3,563 (table 5).

The items included in computing return to assets were the trucks (further described in the semifixed cost section), the items from table 4, land, net cash, and inventories. Inventories were of tires with a total value of $7,400 and repair parts with a value of $12,500.

The management and office salaries and administrative costs were primarily derived from the haulers as were the State licenses and miscellaneous taxes. The licenses and taxes vary considerably by region. The Federal highway use tax rate was obtained from Internal Revenue Service (IRS) Publication 349.

Truck insurance rates vary depending on territory, driving record, length of haul, insurance coverage, type of equipment and cargo, area, and size of business. The following insurance coverage was assumed for each truck:

Liability--Bodily injury	
($300,000 per occurence, $100,000 per person)	$1,302
Collision--$250 deductible	
Tractor	1,352
Trailer	681
Cargo--Payload of $5,000	200
	$3,535

In addition, comprehensive insurance cost on buildings was assumed at $2 per $1,000 valuation.

Table 5--Return to assets, per bulk-milk truck, spring 1976

Item	Total investment costs	Investment per truck	Return to assets per truck 1/
		Dollars	
Tractor--10 units	380,000	38,000	1,900
Trailer--13 units	240,500	24,050	1,202
Shop	38,400	3,840	192
Land	7,500	750	38
Office equipment	2,500	250	12
Shop equipment	12,000	1,200	60
Pickup truck	5,000	500	25
Net cash	7,000	700	35
Inventories			
Tires	7,400	740	37
Parts	12,500	1,250	62
Total	712,800	72,280	3,563

1/ Based on 10-percent return on the midlife value of the assets.

Semifixed Costs

Two items were included as semifixed costs, truck depreciation and driver compensation. These two items exhibit some of the properties of fixed costs and some of the properties of variable costs, so they were specified in a separate category. This method of specification does not change the final results.

Where trucks had low annual mileages the cost of truck depreciation was assumed due to obsolescence over time. For higher mileages, it was due to miles traveled. Driver compensation is a discrete function because of the changes in fringe benefits at different mileages.

The trucks in this study were assumed to conform to a maximum gross weight road limit of 73,280 pounds. Although many States are presently above this weight limit, it is still the common weight allowed in many leading milk-producing States in the Midwest and Northeast.

The truck tractor in this study was assumed to have a conventional cab with sleeper. The trailer had a standard 5,750-gallon stainless steel tank. To conform with weight limits and common operating practices, the tank was assumed to carry 47,500 pounds of milk, almost 2,000 pounds under capacity.

Since the tractor is the largest fixed cost of the business, the milk hauler attempts to maximize utilization of the tractor. However, given the time-consuming nature of loading and unloading in milk hauling, more than one trailer per tractor is required to meet this objective. Thus, the trailer often operates as a storage unit, especially on the weekend. Therefore, this study assumed 1.3 trailers per tractor were required for an efficient business.

The cost estimates for the trucks were based on information from both haulers and equipment dealers. The firm size assumption of an established 10-tractor business permitted a bulk-rate fleet price from equipment dealers. The purchase of new equipment based on current costs was assumed, and the depreciation allowance should leave the firm in the same position at all times in order to reflect actual costs as opposed to accounting costs based on previous purchases.

The annual depreciation was computed by taking the original cost of the equipment less the cost of tires and the salvage value and applying the usable life. The straight-line method of depreciation was used.

This study assumed 7 years as the maximum usable life of a tractor and 12 years as the maximum usable life of a trailer (table 6). The tractor had an estimated lifetime mileage of 700,000 miles (100,000 miles per year) and the trailer had an estimated lifetime mileage of 1 million miles (83,333 miles per year).

Table 6--Bulk-milk truck valuation and depreciation per truck, spring 1976

Item	Original cost 1/	Salvage value 2/	Total depreciation	Years of depreciation	Depreciation per year
	Dollars			Years	Dollars
Tractor	36,356	9,089	27,267	7	3,895
Trailer 3/	22,344	5,586	16,758	12	1,396
Total	58,700	14,675	44,025	--	5,291

1/ The value of the tires is not included in the original cost for purposes of depreciation. Tires were valued at $1,644 for the tractor and $1,706 for the trailer.
2/ The salvage value was assumed at 25 percent of the original cost for both the tractor and trailer.
3/ 1.3 trailers are assumed for each tractor.

Maximum usable life is the estimated number of years when obsolescence becomes the basis for depreciation. In practice, there is substantial variation in the number of years over which trucks are depreciated. Although the annual mileages were larger and the depreciation schedules were shorter for many milk-hauling firms in this study, the use of maximum usable life allows for the analysis of much lower annual mileage associated with shorter trip lengths without cost distortion.

The assumed 1976 original cost of the tractor was $38,000 and for the trailer was $18,500 ($24,050 for 1.3 trailers). The salvage values for both tractor and trailer were assumed to be 25 percent of original costs.

The resulting annual depreciation for the tractor was $3,895 for the first 100,000 miles driven each year, plus 3.90 cents for each additional mile. The trailer depreciation was $1,396 for the first 83,333 miles plus 1.68 cents for each additional mile for 1.3 trailers.

Driver compensation methods vary considerably among trucking firms. Common methods are cents per mile, dollars per hour, a fixed percent of the trip revenue, or some combination of the above. The level of compensation varies by region and the degree of unionization. Rates were reported which varied from 11.5 to 15.6 cents per mile.

Since driver compensation is one of the largest costs of transporting milk, it is broken down in some detail in this study (table 7). Driver compensation of 14 cents a mile for single drivers and 16 cents a mile for a two-man driving team were based on hauler data and labor contracts filed with the Bureau of Labor Statistics. Two-man driving teams were used for all trips over 225 miles one-way to meet the DOT regulations cited earlier on driving time permitted between rest periods. Fringe benefits were assumed to include the employer's contributions to social security, unemployment compensation insurance, workmen's compensation insurance, pension and welfare plans, and vacation and holidays.

Variable Costs

The largest component of the variable costs of operation was fuel. Since the firm operated from a terminal base, it was assumed 60 percent of the fuel source was supplied from the base and 40 percent was obtained on the road for all trip lengths. Average diesel fuel cost was 46 cents per gallon from the terminal and 53 cents per gallon from the road, which yielded a weighted average of 49 cents per gallon. The trucks were assumed to average 5.4 miles per gallon for one-way loaded trips. The resultant fuel cost used in this study was 9.07 cents per vehicle mile (table 8).

The study assumed a level of regular preventive maintenance to avoid reduced equipment utilization and high costs of roadside repairs. In addition, maintenance costs included overhauls. Total maintenance costs were 7.26 cents per mile.

Table 7--Driver compensation, bulk-milk truck, spring 1976

Item	Cost
Base pay (one driver) 1/	14 cents per mile
Base pay (two-man driving team) 1/	16 cents per mile
Social security 2/	5.85 percent of first $15,300
Unemployment compensation insurance 3/	2.5 percent of first $4,200
Workmen's compensation insurance 4/	4.65 percent of total salary
Pension and welfare 5/	0.67 cent per mile
Vacation and holidays 6/	0.82 cent per mile

1/ Based on hauler and labor contract data.
2/ Based on 1975 Federal tax rate.
3/ Based on average rate from Wisconsin, Iowa, New York, Pennsylvania, and California.
4/ Based on data furnished by National Council on Compensation Insurance.
5/ Based on $10 per week and 1,500 miles per week.
6/ Based on $10,000 annual salary, 2 weeks' vacation, 7 paid holidays, and 1,500 miles per 6-day week.

Table 8--Variable costs per vehicle mile for operating a bulk-milk truck, spring 1976

Item	Cost
	Cents
Fuel 1/	9.07
Maintenance:	
Grease and oil	0.56
Repairs (including parts and labor)	6.70
Tires	1.77
Miscellaneous 2/	1.00
Total	19.10

1/ Based on an average of 49 cents per gallon for diesel fuel and 5.4 miles per gallon average for the total trip.
2/ Includes road tolls, weighing fees, fines, and other transportation expenses.

Table 9--Tire cost and wear for a bulk-milk truck, spring 1976

Tires	New tire cost per tire	New tire tread wear per tire	Recapping cost per tire 1/	Recap tread wear per tire	Total cost per tire	Total miles per tire	Estimated average cost per tire per mile	Estimated average cost per truck per mile
	Dollars	Miles	Dollars	Miles	Dollars	Miles	------ Cents	------
Tractor-front (2 tires)	122	80,000	50	60,000	172	140,000	0.1229	0.25
Tractor-driver (8 tires)	175	175,000	58	60,000	233	235,000	.0991	.79
Trailer (8 tires)	164	175,000	50	60,000	214	235,000	.0911	.73
Total (18 tires)	--	--	--	--	--	--	--	1.77

1/ Assumes 1 recapping per tire.
2/ Government regulations prevent using recapped tires on the front of the tractor; therefore, these will probably be used on the trailer.

Tire costs and wear (table 9) were obtained in discussions with haulers and tire dealers. Haulers in different regions had different tire wear and number of recappings, due to varying road conditions and driving practices. Large variation also existed among haulers on recapping practices. Many did no recapping, citing the destruction of fenders with a tire failure as the reason while others used more expensive radial tires and recapped up to five times. Total tire costs averaged 1.77 cents per mile.

RESULTS OF ANALYSIS

Data Required for Model Implementation

Two types of data were needed for the derivation of the truck cost of hauling bulk milk long distance:

(1) Operational conditions specifying trip lengths and hours required per trip length.

(2) Transportation cost relationships specifying the costs at varying trip distances.

The operational conditions were based on the assumptions presented earlier in tables 1 and 2 while the cost relationships were based on the information in tables 3, 4, 5, 6, 7, 8, and 9.

Operational Conditions

The operational conditions were based on the assumptions presented in tables 1 and 2. The round-trip mileage (M) analyzed for this model varied between 200 and 3,000 miles which is equivalent to 100 to 1,500 one-way miles ($M_1 = M/2$). The equipment mix by the industry for trips shorter than 200 round-trip miles may vary from the type of equipment assumed in this report, to equipment with a much smaller capacity. At the other trip length extreme, about the farthest that fluid milk is presently transported is 3,000 round-trip miles. The final costs are presented in one-way mileages, which is standard industry practice. The hours per trip length (table 1) are specified by:

$$H_i = 12 + M/45$$

Where H = hours per trip length, 12 is the fixed number of hours associated with all trips, and 45 miles per hour is the average speed of trucks. The subscript i (i = 200...3,000) designates round-trip length in miles.

The total number of trips per year (table 2) is a function of the total annual number of hours available and the number of hours per trip:

$$TS_i = 5,602/H$$

where TS_i = number of trips per year (seasonal) and 5,602 is the total number of hours available per year after adjusting for seasonality and repairs.

Restating the above in another form, the total mileage per year per trip length (table 2) can be expressed as:

$$TMS_i = (M)\ (TS_i)$$

where TMS_i is total mileage per year per trip length (seasonal).

These operational conditions form the basis for the following transportation cost relationships.

Transportation Costs

The fixed cost can be written as:

$$F_j = \frac{\$12{,}866}{(M_1)(TS_i)} \times 100$$

where F_j is fixed cost per one-way mile per trip, \$12,866 is the total annual fixed cost per truck (table 3), and subscript j (j = 100...1,500) denotes one-way trip length in miles.

There were two semifixed cost items included in the transportation model, truck depreciation and driver wages. Truck depreciation is specified by the following:

$$D_j = \frac{\$5{,}291 + \$.0168(TMS_i > 83{,}333) + \$.0390(TMS_i > 100{,}000)}{(M_1)(TS_i)} \times 100$$

where D_j is truck depreciation per mile per trip. The \$5,291 is total depreciation per truck per year based on an estimated lifetime mileage rate of 100,000 miles or less per year for the tractor and 83,333 miles or less per year for the trailer (table 6). This is the normal rate of depreciation due to obsolescence and normal wear. However, when either tractor or trailer mileages exceed the above rate, \$.0390 per mile (\$3,895/100,000 miles) is added to depreciation for the tractor and \$.0168 per mile (\$1,397/83,333 miles) is added for the trailer (table 6).

Driver wages were specified by the following two equations:

$$W_{j(M_1 \leq 225)} = \frac{\begin{bmatrix} \$.1549\ TMS_i + \$.13\ (\$.1549\ TMS_i) \\ \$-.0250\ (\$.1549\ TMS_i,\ \text{where}\ \$.1549\ TMS_i > \$4{,}200) \\ \$-.0585\ (\$.1549\ TMS_i,\ \text{where}\ \$.1549\ TMS_i > \$15{,}300) \end{bmatrix}}{(M_1)(TS_i)} \times 100$$

and

$$W_{j(M_1 > 225)} = \frac{\begin{bmatrix} \$.1898\ TMS_i + \$.13\ (\$.1898\ TMS_i) \\ \$-.0250\ (\$.1898\ TMS_i,\ \text{where}\ \$.1898\ TMS_i > \$8{,}400) \\ \$-.0535\ (.1898\ TMS_i,\ \text{where}\ \$.1898\ TMS_i > \$30{,}600) \end{bmatrix}}{(M_1)(TS_i)} \times 100$$

where W represents driver wages per mile per trip (table 7). One driver was used for trip distances of less than 225 miles one-way at a base driver cost of 14 cents per mile. Two drivers were used for trip distances of more than 225 miles at a base driver cost of 16 cents per mile.

In addition, 1.49 cents per mile were added per driver for pension, welfare, vacation, and holidays. Thirteen percent of this was added for fringe benefits, 5.85 percent was subtracted above $15,300 annual salary for social security, and 2.5 percent was subtracted above $4,200 for unemployment compensation insurance.

The variable cost per mile is written as:

$$V = 2\ (\$.192)$$

where V represents variable cost per mile (table 8) which does not change over the various trip lengths.

The above costs are combined by the following:

$$TCM_j = F_j + V_j + W_j + V,$$

$$TCC_j = \frac{(M_1)\ (TCM_j)}{475}$$

and

$$TCCM_j = TCM_j/475$$

where TCM_j is total cost per mile per trip, TCC_j is total cost per hundredweight per trip, and TCCM is total cost per hundredweight per mile per trip. The 475 represents hundredweight per truck.

The above transportation cost functions were used to derive the baseline cost figures in table 10. These are the costs of milk transportation given the assumptions on firm size and conduct in this report and the operational conditions also specified above. Selected modifications of these assumptions were used to develop the alternative cost situations in tables 11, 12, 13, and 15. These cost functions can also be used to develop costs for any mileages not shown in the tables, or the assumptions made can be modified to show additional cost situations.

A least squares regression analysis was used to develop the statistical relationship between hundredweight and mileage. Fifty-seven observations at 25-mile intervals were used in the analysis of one-way trip distances between 100 and 1,500 miles. Since each of the component costs was almost linear over alternative mileages, all of the resultant equations explained over 99 percent of the variation in costs.

Table 10--Estimated cost of transporting bulk milk over selected trip lengths, spring 1976 1/

One-way mileage	Cost per mile					Cost per cwt	Cost per cwt per mile
	Fixed	Semifixed		Variable	Total		
		Truck depreciation	Driver wages				
	Cents						
100	37.8	15.6	34.2	38.2	125.7	26.5	0.265
150	28.6	15.1	34.2	38.2	116.1	36.7	.244
200	24.0	21.0	34.2	38.2	117.4	49.4	.247
250	21.2	19.9	42.0	38.2	121.3	63.8	.255
500	15.7	17.6	39.7	38.2	111.3	117.1	.234
750	13.9	16.9	39.7	38.2	108.7	171.6	.229
1,000	13.0	16.5	39.7	38.2	107.4	226.1	.226
1,250	12.4	16.3	39.7	38.2	106.6	280.5	.224
1,500	12.0	16.1	39.7	38.2	106.1	335.0	.223

1/ Based on 5,602 hours per year and a 47,500-pound payload.

Baseline Transportation Costs

The costs shown in table 10 are for selected one-way trip lengths from 100 through 1,500 miles, for seasonal conditions (5,602 hours annually), and for a 47,500-pound payload. The three average costs presented are in terms of (1) mileage, (2) hundredweight, and (3) hundredweight per mile. The average mileage costs are further divided into fixed, semifixed, and variable. One-way mileage is used for convention since rates quoted by the trade are expressed in terms of a one-way trip.

The resulting costs declined in cost per one-way mile with increased mileage except in the 200- to 250-mile interval. The total cost per mile tended to flatten out beyond 600 miles one-way, declining from $1.10 at 600 miles to $1.06 at 1,500 miles.

The total cost decline is partially due to spreading the constant fixed cost of transportation over the increased mileage. Fixed cost per mile declined from 37.7 cents for 100-mile trips to 12.0 cents for 1,500-mile

trips. Truck depreciation cost per mile also shows a decline to 16.1 cents for 1,500-mile trips. However, depreciation cost is a step function with breaks at 133 miles and 177 miles due to the break between obsolescence and mileage depreciations specified at these points. Driver wages were relatively constant over different trip lengths, being 39.7 cents at 400 miles and greater. However, driver wages exhibit some steps below 400 miles. There were decreases at 150 and 275 miles due to fringe benefits such as social security and unemployment compensation insurance. In addition an increase in driver wages occured at 225 miles due to the use of two drivers per truck. Two drivers were used in this analysis to avoid the increased investment of an additional 8 hours of time for the layover required by one driver. Variable cost remains at a constant 38.2 cents per one-way mile over all mileages.

The hundredweight costs for one-way distance between 100 and 1,500 miles were used in regression analysis to develop a total baseline cost function for transporting milk:

$$Y=7.67 + .218X$$

In this function, X denotes one-way mileage and Y denotes bulk-milk transportation costs in cents per hundredweight.

Alternative Transportation Costs

Given the baseline milk transportation costs as a standard for this study, several alternatives were considered to determine their resultant transportation costs in comparison to the baseline. Alternatives were considered in the method of truck depreciation, seasonality, plant receiving schedules, speed limit, fuel tax rate, and tank size. Finally, the transportation costs were projected to 1985.

Alternative Truck Depreciation Costs

Truck depreciation in this alternative was based on the average price of the trucks at purchase rather than on 1976 values, a common practice in the industry. The average value of the tractors was $28,600 and the average value of the 1.3 trailers was $19,266. The total annual depreciation for the trucks was $4,056.

The lower transportation costs from this alternative are reflected in the cost per mile (table 11). For example, the cost per mile at 1,500 miles was 101.5 cents compared to 106.1 cents for the baseline. The functional relationship developed for this alternative, $y = 7.15 + .209x$, also shows a somewhat lower 0.209 cent increase in cost per hundredweight for each one-way mile increase in trip distance, when compared to the baseline developed function which showed 0.218 cent.

Table 11--Estimated cost of transporting bulk milk using average truck valuation, spring 1976

One-way mileage	Cost per mile 1/	Cost per cwt per mile
	Cents	
100	119.4	0.251
150	110.7	.233
200	118.5	.249
250	115.1	.242
500	106.0	.223
750	103.7	.218
1,000	102.6	.216
1,250	101.9	.215
1,500	101.5	.214

1/ $y = 7.15 + .209x$
where: x denotes one-way mileage and y denotes cost per cwt.

Alternative Seasonality Costs

One of the principal assumptions in this study was the use of a 68-percent industry capacity due to the seasonality of milk transportation. However, this level of seasonality is somewhat arbitrary since it varies from year to year and between regions of the country. Therefore, three other levels of seasonality were examined as to their effects on transportation costs (table 12). They were (1) no seasonality or 100-percent capacity, (2) 1975 milk production seasonality or 81-percent capacity (6), and (3) Wisconsin seasonality or 57-percent capacity.

The alternative of no seasonality assumed 8,292 hours per year available for transportation and resulted in an increase in cost per hundredweight of 0.209 cent for each mile increase. The fluctuations in milk production in 1975 were used as a second seasonality alternative (6,741 hours) and resulted in an increase in cost per hundredweight of 0.213 cent for each mile increase. The third seasonality alternative attempted to show the effects of geographic differences in seasonality. For example, one of the areas with the highest seasonality in milk hauling is Wisconsin while the milk-hauling industry in

Table 12--Estimated cost of transporting bulk milk with alternative seasonality assumptions, spring 1976

One-way mileage	No seasonality 8,292 hours 1/		1975 seasonality 6,741 hours 2/		Wisconsin seasonality 5,025 hours 3/	
	Cost per mile	Cost per cwt per mile	Cost per mile	Cost per cwt per mile	Cost per mile	Cost per cwt per mile
	Cents					
100	117.8	0.248	116.7	0.246	131.9	0.278
150	109.0	.229	115.3	.243	117.4	.247
200	114.2	.240	119.5	.252	121.3	.255
250	109.3	.230	116.2	.245	124.7	.263
500	104.1	.219	107.5	.226	116.1	.244
750	102.3	.215	105.4	.222	110.9	.233
1,000	101.5	.214	104.3	.220	109.5	.231
1,250	100.9	.212	103.7	.218	108.6	.229
1,500	100.6	.212	103.2	.217	108.0	.227

1/ $y = 4.99 + .209x$
2/ $y = 6.30 + .213x$
3/ $y = 9.31 + .222x$

where: x denotes one-way mileage and y denotes cost per cwt.

the East is faced with a much lower seasonality. An average of the actual seasonality of operation of a few selected haulers in Wisconsin was used (5,025 hours), with a resulting increase in cost per hundredweight of 0.222 cent for each mile increase.

Alternative Institutional Costs

The effects on transportation costs of four selected institutional changes were evaluated in table 13. The four changes were (1) 24-hour plant unloading, (2) a 55-mile-per-hour average actual driving speed for the trucks, (3) an increase in the Federal fuel tax to 14 cents per gallon, and (4) an increase in tank size to 6,200 gallons.

Table 13--Estimated cost of transporting bulk milk with alternative institutional assumptions, spring 1976

One-way mileage	24-hour plant unloading 1/		55-mph average speed 2/		Federal fuel tax 14¢ per gallon 3/		6,200 gallon tank 4/	
	Cost per mile	Cost per cwt per mile	Cost per mile	Cost per cwt per mile	Cost per mile	Cost per cwt per mile	Cost per mile	Cost per cwt per mile
	Cents							
100	109.2	0.230	123.1	0.259	129.5	0.273	125.7	0.245
150	104.8	.221	113.5	.239	119.9	.252	116.1	.226
200	110.0	.232	122.5	.258	128.9	.271	115.6	.225
250	108.7	.229	118.7	.250	125.0	.263	121.3	.236
500	106.1	.223	108.7	.229	115.0	.242	111.3	.217
750	105.2	.221	106.1	.223	112.4	.237	108.7	.211
1,000	104.8	.221	104.8	.221	111.1	.234	107.4	.209
1,250	104.5	.221	104.0	.219	110.3	.232	106.6	.207
1,500	104.4	.220	103.5	.218	109.4	.231	106.1	.206

1/ $y = 2.18 + .218x$
2/ $y = 7.72 + .212x$
3/ $y = 7.94 + .226x$
4/ $y = 7.34 + .202x$

where: x denotes one-way mileage and y denotes cost per cwt.

The baseline cost estimates assumed that an additional 8 hours per trip were required due to the nature of plant receiving schedules. The elimination of this requirement resulted in no decreases in cost with increased mileage, but rather lowered the constant in the cost function from 7.67 cents to 2.18 cents. Or, the cost per mile at 1,500 miles one-way was lowered from the baseline estimate of 106.1 cents to 104.4 cents. Although 24-hour plant unloading was felt to be an unrealistic assumption, it does show the relative cost of restrictive plant unloading schedules.

Compared with other alternatives, a 10-mile-per-hour increase in speed limit has only minor effects on reducing transportation costs. For the change in truck speed, it was assumed an increase in the speed limit from 55 to 65 miles per hour would result in an equal increase in average truck speed from 45 to 55 miles per hour. This resulted in an increase in cost per hundredweight of 0.212 cent for each mile increase in distance compared to 0.218 for the 45-mile-per-hour average speed.

The change in Federal gas tax examined was an increase of 10 cents per gallon from the 4 cents per gallon in the baseline. The resultant 14-cent tax yielded an increase in cost per hundredweight of 0.226 cent for each mile increase.

The assumption of a 73,280-pound maximum road limit restricts the bulk-tank trailer size to 5,750 gallons or 47,500 pounds. Arbitrarily raising the road limit to 80,000 pounds would allow the use of 6,200-gallon tanks capable of carrying 51,400 pounds. Heavier capacity is a realistic alternative as more key milk-producing States such as California switch to the 80,000 pound limit. This study ignored the marginally higher equipment costs associated with the larger tanks because the effect on transportation costs would be minimal and just examined the transportation costs associated with the larger capacity. Therefore, the cost per mile remained the same as the baseline costs. However, the cost per hundredweight per mile was lower, ranging from 0.206 cent for 1,500-mile trips to 0.245 cent for 100-mile trips.

Projected Costs to 1985

The bulk-milk transportation costs per mile were also estimated for 1985. First, the 1985 input costs were estimated (table 14). Then these input costs were fitted into the previously developed system used for estimating 1976 costs. The only institutional change made was an increase in the road weight limit to 80,000 pounds which is expected to be nationwide by that time.

As expected, 1985 costs per mile were higher for all cost components, fixed, semifixed, and variable (table 15). This resulted in costs per mile 40 to 50 cents higher than 1976 costs over all trip distances.

Table 14--Bulk-milk transportation input prices projected to 1985

Item	Year	
	1976	1985
	Index	
Trucks	100	150
Motor supplies	100	143
Fuels and energy	100	173
Buildings	100	158
Taxes	100	137
Interest	100	159
Labor wages	100	144
Consumer price index	100	153

From reports on dairy programs, Commodity Economics Division, Economic Research Service, USDA.

Table 15--Estimated cost of transporting bulk milk, projected to 1985 1/

One-way mileage	Cost per mile in 1985					Cost per cwt per mile
	Fixed	Semi-fixed		Variable	Total	
		Truck depreci- ation	Driver wages			
	Cents					
100	59.5	23.4	35.6	57.8	176.2	0.342
150	45.0	22.8	35.6	57.8	161.1	.313
200	37.8	31.7	35.6	57.8	162.8	.317
250	33.4	30.0	43.6	57.8	164.8	.321
500	24.8	26.5	43.6	57.8	152.7	.297
750	21.9	25.4	43.6	57.8	148.6	.289
1,000	20.4	24.8	43.6	57.8	146.6	.285
1,250	19.6	24.5	43.6	57.8	145.4	.283
1,500	19.0	24.3	43.6	57.8	144.7	.282

1/ $y = 9.87 + .275x$

where: x denotes one-way mileage and y denotes cost per cwt.

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